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ABSTRACT

Described is the development of an instrument designed to measure the cognitive ability of evaluation in high school chemistry students. The instrument was composed of several situations found in chemistry courses, each designed to measure a student's evaluation ability based on his knowledge of kinetic-molecular theory as it applied to gases, liquids, and solids. There was no significant difference in knowledge ability between students taught in modern and traditional courses. An analysis of variance of class mean scores revealed that students from modern courses had a significantly higher (.01 level) evaluation ability. (RS)

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AN INSTRUMENT TO MEASURE THE COGNITIVE ABILITY EVALUATION OF THE TAXONOMY

By

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A Paper Presented at the 1970
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AN INSTRUMENT TO MEASURE THE COGNITIVE ABILITY EVALUATION OF THE TAXONOMY

With the trend of new science curricula having a purpose of developing high level mental abilities in students (Goodlad, 1966), several investigators have conducted studies incorporating tests based on the Taxonomy of Educational Objectives, Handbook 1: Cognitive Domain (Bloom, 1956) to measure student performance. These tests have produced distinct insights in identifying the complex behaviors developed, but have been relatively unsuccessful in measuring the high level cognitive ability of Evaluation. This report describes the development of a Taxonomy based instrument, Assessment of EVALUATION Ability in Chemistry, Part Ii, designed to measure the cognitive ability Evaluation in high school chemistry students.

Background

The Taxonomy is a standard classification system for educational objectives designed to facilitate the exchange of information among teachers who are concerned with curriculum developments and related evaluation devices. This work was developed as an educational-logical-psychological classification system. Primary importance was given to educational considerations with the boundries between categories closely related to distinctions made by teachers when planning curricula or in choosing learning situations. Considerable effort was made to avoid value judgments about the objectives and behaviors by constructing a comprehensive system in which one could classify all of the objectives which might be stated as descriptions of student behavior.

Teacher practices and instructional methods are not classified in the Taxonomy. It concentrates on student behaviors which represent the intended outcomes of the educational process. These intended behaviors represent the manner in which students act, think, or feel after participating in a unit of instruction: specific human behaviors that depict intellectual functioning. They do not include the objectives that are of interest to many psychologists which specify social and emotional adjustments.

Six major categories of cognitive behavior are represented in the Taxonomy. A condensed description of these categories, Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation are presented in Handbook I: Cognitive Domain (Bloom, 1956 pp. 201-207). These cognitive categories were developed to represent a hierarchical structure that is cumulative in nature from the lowest category, Knowledge, through the highest category, Evaluation. Therefore, the highest or most complex category, Evaluation, involves a complex intellectual functioning which may include the functions of all the subordinate categories in the hierarchy.

Following publication of the Taxonomy, considerable effort has been expended in developing course examinations based on this classification system. Initial efforts consisted primarily of classifying existing classroom test questions according to the different categories of the hierarchy. This produced collections of test items representing the various categories for each of several academic disciplins (Dressel and Nelson, 1956; Lessinger, 1963). A majority of the items collected was classified into the lower level categories of Knowledge, Comprehension, and Application.

Later several investigators focused their research on the construction of Taxonomy based tests for specific evaluation purposes (Anderson, 1964; Herron, 1966; Kropp, Stoker, and Bashaw, 1966; McFall, 1964; McGuire, 1963; and Stoker and Kropp, 1964). These instruments incorporated single items (questions) of the multiple-choice style with unequal numbers of items corresponding to each of the major categories. Each item represented a sample from a universe of content and it was apparently assumed that the items were of equal weight. Results of the studies led some investigators to question the extent to which the multiple-choice items were measuring the mental process of Evaluation.

Design of the Instrument

The Evaluation test was designed to measure a student's Evaluation ability based on his knowledge of Kinetic-Molecular Theory as it applied to gases, liquids, and solids. It was composed of several problems, each presenting a different situation

related to the topics taught in high school chemistry courses. Each problem was broken down into a series of five relatively specific items calling for separate judgments based on different criteria. This was done in order to measure as much of the Evaluation process as possible. All of the items called for a YES or NO response to a statement which was followed by a request for an explanation of the decision given. The combined YES-NO response and explanation for each item was considered to be a single response. Both parts of the response were considered necessary in the scoring process. The item was considered correct if the criteria presented in the explanation supported the YES or NO checked and were in accordance with the Evaluation process as described in the Taxonomy. Since either a YES or NO judgment could have been given for several items, the decision for determining whether the item was correct or incorrect depended upon the evidence the student gave in the written explanation. The Evaluation test, Assessment of Evaluation Ability in Chemistry, Form J, Part II, contained nine problems with five items each for a total of forty-five student responses. (Appendix 1)

Kinetic Molecular Theory is taught relatively early in the school year in most high school chemistry courses. The instrument was designed to be administered at the end of the school year to allow for the process of Evaluation to be developed in courses having this objective as they progressed. This also permitted the basic ideas associated with Kinetic-Molecular Theory to be re-examined in different contexts throughout the course.

In the past, tests designed to measure student cognitive abilities have included one or more reading passages of related information. These reading passages have served various functions, depending on the viewpoint of the author. One purpose of the reading passage was to provide sufficient information for answering the test questions. Another purpose was to present factual information and basic ideas needed as a basis to formulate responses to the items. A reading passage was not included as a part of this instrument because its function was to measure abilities developed

and retained from the course and not from a reading passage provided.

Equivalent form

An equivalent form of the Evaluation test was produced by revising the Evaluation test of Form J of the instrument. Minor changes were incorporated into each of the nine problems. This was followed by using a random procedure to change the order of the problems. The order of the five items subordinate to each problem was not changed. However, changes were made in the items associated with some problems to conform to changes made in the problem. The revised Evaluation test was Assessment of Evaluation Ability in Chemistry, Form S, Part II of the criterion instrument.

Validation of the Instrument

The instrument was validated both for content validity and for cognitive ability (process) validity. Separate and identical validation procedures were used for both Form J and Form S. Two groups of judges were used for the validation processes. One group of judges, possessing appropriate backgrounds in chemistry content and experience with high school chemistry programs, determined the content validity of the instrument. The cognitive ability validity of the instrument was determined by a second group of judges possessing a working understanding of the Taxonomy.

The role of the judges in the cognitive ability validation was different in this situation from that described in previous studies. Generally, the role of the judges has been that of classifying a group of selected items provided to them into the several categories of the Taxonomy. In the validation procedure reported here, the role of the judges was to determine if the items were properly classified in the category important to this investigation. They were not requested to reclassify any items they judged not properly classified. In essence, the role of the cognitive ability validation judges was to verify the classification of the items which were constructed specifically for the Evaluation category.

Content validation

A group of three judges having teaching experience and an understanding of high school chemistry programs was selected to determine the content validity of the instrument. These judges have taught high school chemistry, and have had recent experience with curriculum materials designed for high school chemistry. In addition, they have taught chemistry at the college level. Each of the three judges worked independently in rating the test items. The results of the rating of the items by the judges are presented in Tables 1 and 2 for the Evaluation tests.

Cognitive ability (process) validity

Four judges with an understanding of the Taxonomy and recent experience on research projects using Taxonomy based tests were selected to determine the cognitive ability validity of the instrument. Professors in educational research and testing served as three of the judges. These individuals have demonstrated a strong interest in the use of the Taxonomy in conjunction with educational testing. Two judges were principal investigators in a long term study concerned with the validation of the hierarchy of taxonomic processes. In addition, one has authored articles describing the uses of the Taxonomy, and discussing problems associated with its use in educational measurement. The fourth judge presented a unique experience of having developed a test in chemistry, based on all of the taxonomic processes, that was used in a recent study. The four judges independently rated the test items. The results of their ratings for cognitive ability validity are presented in Tables 3 and 4 for the Evaluation tests.

Results of validation

Forty-four of the forty-five items in the tests received a unanimous YES rating by the judges for content validity or cognitive ability validity. Item nine of Form J received two of three possible YES ratings from the content validity judges and three of four potential YES ratings from the cognitive ability validity judges. Its equivalent, item thirty-nine in Form S, received an

TABLE 1

CONTENT RATING OF EVALUATION TEST ITEMS
PART II, FORM J

Item	Judge			Item	Judge			Item	Judge			Item	Judge		
	A	B	C		A	B	C		A	B	C		A	B	C
1	YES	YES	YES	13	YES	YES	YES	24	YES	YES	YES	35	YES	YES	YES
2	YES	YES	YES	14	YES	YES	YES	25	YES	YES	YES	36	YES	YES	YES
3	YES	YES	YES	15	YES	NO	YES	26	YES	YES	YES	37	YES	YES	YES
4	YES	YES	YES	16	YES	YES	YES	27	YES	YES	YES	38	YES	YES	YES
5	YES	YES	YES	17	YES	YES	YES	28	YES	YES	YES	39	YES	YES	YES
6	YES	YES	YES	18	YES	YES	YES	29	YES	YES	YES	40	YES	YES	YES
7	YES	YES	YES	19	YES	YES	YES	30	YES	YES	YES	41	YES	YES	YES
8	YES	YES	YES	20	YES	YES	YES	31	YES	YES	YES	42	YES	YES	YES
9	YES	NO	YES	21	YES	YES	YES	32	YES	YES	YES	43	YES	YES	YES
10	YES	YES	YES	22	YES	YES	YES	33	YES	YES	YES	44	YES	YES	YES
11	YES	NO	YES	23	YES	YES	YES	34	YES	YES	YES	45	YES	YES	YES
12	YES	YES	YES												

TABLE 2

CONTENT RATING OF EVALUATION TEST ITEMS
PART II, FORM S

Item	Judge			Item	Judge			Item	Judge			Item	Judge		
	A	B	C		A	B	C		A	B	C		A	B	C
1	YES	NO	YES	13	YES	YES	YES	24	YES	YES	YES	35	YES	YES	YES
2	YES	YES	YES	14	YES	YES	YES	25	YES	YES	YES	36*			
3	YES	YES	YES	15	YES	YES	YES	26	YES	YES	YES	37	YES	YES	YES
4	YES	YES	YES	16	YES	YES	YES	27	YES	YES	YES	38	YES	YES	YES
5	YES	YES	YES	17	YES	YES	YES	28	YES	YES	YES	39	YES	NO	YES
6	YES	YES	YES	18	YES	YES	YES	29	YES	YES	YES	40	YES	NO	YES
7	YES	YES	YES	19	YES	YES	YES	30	YES	YES	YES	41	YES	YES	YES
8	YES	YES	YES	20	YES	YES	YES	31	YES	YES	YES	42	YES	YES	YES
9	YES	YES	YES	21	YES	YES	YES	32	YES	YES	YES	43	YES	YES	YES
10	YES	YES	YES	22	YES	YES	YES	33	YES	YES	YES	44	YES	YES	YES
11	YES	YES	?	23	YES	YES	YES	34	YES	YES	YES	45	YES	YES	YES
12	YES	YES	YES												

*Item not rated

TABLE 3

COGNITIVE ABILITY RATING OF EVALUATION TEST ITEMS
PART II, FORM J

Item	Judge				Item	Judge				Item	Judge				Item	Judge			
	A	B	C	D		A	B	C	D		A	B	C	D		A	B	C	D
1	YES	YES	NO	YES	13	YES	YES	YES	YES	24	YES	YES	YES	YES	35	YES	YES	YES	YES
2	YES	YES	YES	YES	14	YES	YES	YES	YES	25	YES	YES	YES	YES	36	YES	YES	NO	YES
3	YES	YES	NO	YES	15	YES	YES	YES	YES	26	YES	YES	YES	YES	37	YES	YES	NO	YES
4	YES	YES	YES	YES	16	YES	YES	NO	YES	27	YES	YES	YES	YES	38	YES	YES	NO	YES
5	YES	YES	NO	YES	17	YES	YES	NO	YES	28	YES	YES	YES	YES	39	YES	YES	YES	YES
6	YES	NO	YES	YES	18	YES	YES	NO	YES	29	YES	YES	YES	YES	40	YES	YES	NO	YES
7	YES	YES	YES	YES	19	YES	YES	YES	YES	30	YES	YES	YES	YES	41	YES	NO	YES	YES
8	YES	NO	NO	YES	20	YES	YES	YES	YES	31	YES	YES	YES	YES	42	YES	NO	YES	YES
9	YES	NO	YES	YES	21	YES	YES	YES	YES	32	YES	YES	YES	YES	43	YES	NO	YES	YES
10	YES	NO	YES	YES	22	YES	YES	YES	YES	33	YES	YES	YES	YES	44	YES	YES	YES	YES
11	YES	YES	YES	YES	23	YES	YES	YES	YES	34	YES	YES	YES	YES	45	YES	YES	YES	YES
12	YES	YES	YES	YES															

TABLE 4

COGNITIVE ABILITY RATING OF EVALUATION TEST ITEMS
PART II, FORM S

Item	Judge				Item	Judge				Item	Judge				Item	Judge			
	A	B	C	D		A	B	C	D		A	B	C	D		A	B	C	D
1	YES	YES	YES	YES	13	YES	YES	NO	YES	24	YES	YES	YES	YES	35	YES	YES	YES	YES
2	YES	YES	YES	YES	14	YES	YES	YES	YES	25	YES	YES	YES	YES	36*				
3	YES	YES	YES	YES	15	YES	YES	YES	YES	26	YES	YES	NO	YES	37	YES	YES	NO	YES
4	YES	YES	YES	YES	16	YES	YES	NO	YES	27	YES	YES	NO	YES	38	YES	NO	NO	YES
5	YES	YES	YES	YES	17	YES	YES	YES	YES	28	YES	YES	NO	YES	39	YES	NO	YES	YES
6	YES	YES	YES	YES	18	YES	YES	NO	YES	29	YES	YES	YES	YES	40	YES	NO	YES	YES
7	YES	YES	YES	YES	19	YES	YES	YES	YES	30	YES	YES	NO	YES	41	YES	YES	NO	YES
8	YES	YES	YES	YES	20	YES	YES	YES	YES	31	YES	YES	YES	YES	42	YES	YES	NO	YES
9	YES	YES	YES	YES	21	YES	YES	YES	YES	32	YES	YES	YES	YES	43	YES	YES	YES	YES
10	YES	YES	YES	YES	22	YES	YES	YES	YES	33	YES	YES	YES	YES	44	YES	YES	YES	YES
11	YES	YES	NO	YES	23	YES	YES	YES	YES	34	YES	YES	YES	YES	45	YES	YES	YES	YES
12	YES	YES	NO	YES															

*Item not rated

identical rating. These results render evidence to support the high consistancy demonstrated by the judges in the validation process.

Results of Test Administration

When the Evaluation test was administered to twenty-four classes representing modern and conventional high school chemistry, an analysis of variance of class mean scores revealed that students given the modern courses performed significantly higher (.01 level). A Knowledge test. administered in conjunction with the Evaluation test showed no difference between the two treatment groups at the .05 level of significance (Schaff and Westmeyer, 1970).

Scoring of Evaluation Items

A persistent problem associated with the use of free-response type items in measuring student performance has been the reliability of grading. In acknowledgement of this problem, a check was made to determine the reliability of the investigator in scoring the evaluation items. The entire group of tests was stratified into conventional and modern subgroups. Five tests were randomly selected from each subgroup producing a set of ten tests representing the entire group. The 450 items contained in these tests were scored independently by two individuals who have taught chemistry in high school and college at the undergraduate level and by the investigator. The results of these independent scorings are presented in Table 5 under Scorers A, B, and C_1. Pearson product-moment correlations of the test scores were computed between all pairs of the three scorers with the following results obtained:

1. between investigator (C_1) and scorer A, $r = .75$
2. between investigator (C_1) and scorer B, $r = .83$
3. between scorer A and scorer B, $r = .66$

A statistical test was conducted to determine a coefficient of stability of the investigator in rating the evaluation items. The set of ten tests containing 450 items was scored a second time by the investigator after a one week interval. These scores are

TABLE 7

SCORES RESULTING FROM INDEPENDENT SCORERS
EVALUATION TEST ITEMS

Test	Scorer			
	A	B	C_1	C_2*
1	20	22	18	22
2	4	12	8	6
3	8	13	10	14
4	13	17	19	20
5	10	26	20	24
6	14	22	14	14
7	2	9	4	6
8	9	18	9	13
9	8	22	15	16
10	10	17	12	10

*Scored after one week interval.

shown in Table 5 under scorer C_2. A Pearson product-moment correlation computed between the two independent sets of scores by the investigator (C_1 and C_2) gave an $r = .92$.

Reliability Estimation

The reliability of the Evaluation test was determined by computing a correlation coefficient between mean class scores obtained following administration of both forms. This method of estimating test reliability using two equivalent forms of the test in a test-retest situation gives a coefficient of equivalence and stability for the test. A Pearson product-moment correlation of .75 was obtained.

Conclusion

This paper has described the development and validation of an instrument to measure the cognitive ability Evaluation as described in the Taxonomy. When administered to high school chemistry classes, the Evaluation test disclosed differences in the cognitive ability Evaluation of students given instruction in modern and traditional courses. These same students demonstrated an equivalent performance in their Knowledge ability. The results for the Evaluation test can be expected, because there is general agreement among educators that the modern curricula are different from their conventional counterparts, and have goals which include the development of students' cognitive abilities. It is recognized that previous attempts to measure students' Evaluation ability have been relatively unsuccessful. This may be because other tests have been designed to measure Evaluation along with several other cognitive abilities within the same test, thus limiting the number of items and the amount of time devoted to each item for the measurement of a student's Evaluation ability.

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Appendix 1

Assessment of Evaluation Ability

In Chemistry

Form J

1968

PART II

Prepared by

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TEST INSTRUCTIONS

Part II

When asked to evaluate something, many students just make quick decisions or give opinions without carefully thinking about the various aspects of the idea, or activity being judged. In this part of the test, you are to answer each question after carefully making a judgment based on the information given in the previous paragraph. Check either a Yes or No answer. In the box immediately below, you are to give an explanation to support your decision. This explanation is a very important part of your answer.

EXAMPLE I.

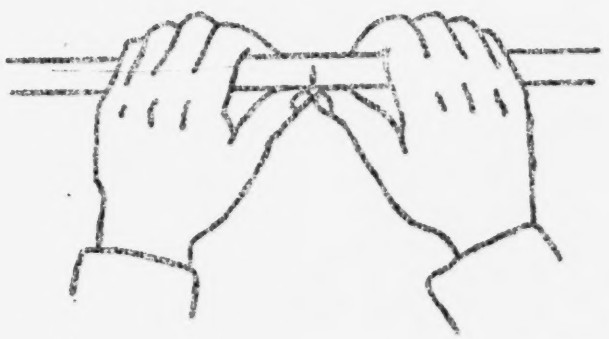

Figure A

Does Figure A show a correct method of holding glass tubing for breaking at the scratch mark? Yes___ No ✓

Explain your answer: *The method shown is incorrect because the scratch mark should be directly opposite the thumbs rather than on top as shown. Also, a paper towel or cloth should be wrapped around the glass tubing to protect the hands.*

Go on to next page →

EXAMPLE II.

The following procedure was given for inserting glass tubing into a rubber stopper.

> "Before attempting to insert glass tubing into a rubber stopper be sure that the ends are fire-polished. Make sure the hole in the stopper is large enough that it will stretch easily to accommodate the tubing. Place a drop of glycerine or some water in the hole of the stopper or on the tip of the glass tube to serve as a lubricant. Protect your hands by wrapping the glass with a piece of cloth or towel. Hold the glass near the stopper and push it with a gentle twisting motion. Do not force excessively as you twist the glass tubing into the stopper. If you experience any difficulty, consult your teacher."

Does the procedure described above represent a good one to use for inserting a glass tube into a rubber stopper?
Yes ✓ No ___

Explain your answer: *The procedure described is a good one because it describes the sequence of events in a logical order. It shows concern for safety by mentioning such points as fire-polishing the ends of the glass tube, using a lubricant, protecting the hands, and what to do if problems arise.*

You Will Be Given 60 Minutes For This Part Of The Test

Do Not Begin Until You Are Told To Do So

I. A five pound coffee can was filled with CO_2 gas to a pressure of 2 pounds per square inch and tightly sealed. Neither the volume of the can nor the temperature of the environment was allowed to change. There was no possibility of a leak developing in the sealed can. When a student was asked to predict what would happen to the pressure of the gas in the can over a long period of time, the following response was given:

> "The pressure exerted by the CO_2 gas in the can will slowly drop over a period of time, e.g., six months, because the particles of CO_2 will lose energy during their collisions."

1. Does our basic understanding of Kinetic-Molecular Theory support the prediction made by the student?
Yes___ No___

Explain your answer:

2. Even though the temperature was not allowed to change, would it be important to know the temperature of the environment when making the prediction?
Yes___ No___

Explain your answer:

3. Was a sufficient amount of information given for the student to make an accurate prediction of what would happen to the pressure of the gas in the can?
Yes___ No___

Explain your answer:

4. Could the student make the same prediction if NH_3 gas had been used in the coffee can instead of CO_2 gas? Yes___ No___

Explain your answer:

5. Could the student make the same prediction if the coffee can had been filled with a mixture of two gases such as H_2 gas and N_2 gas instead of the CO_2 gas? (Assume that the N_2 and H_2 do not react chemically) Yes___ No___

Explain your answer:

II. 100 ml of liquid distilled water was slowly cooled from 15°C to -5°C without changing to ice. The water was in a 250 ml glass beaker at a pressure of 1 atmosphere. At these conditions a small piece of ice (solid) was dropped into the cooled liquid water and the water immediately froze, i.e., changed to a solid. This procedure was repeated three times with the same result obtained each time. It was concluded on the basis of these observations that the freezing point of the distilled water was -5°C at a pressure of 1 atmosphere.

6. Can the above conclusion be explained according to the Kinetic-Molecular Theory of gases and liquids?
Yes___ No___

Explain your answer:

7. Does the procedure described above represent a good method of determining the freezing point of water?
Yes___ No___

Explain your answer:

8. Is the conclusion obtained in the above procedure supported by results obtained from other experiments designed to determine the freezing points of liquids?
Yes___ No___

Explain your answer:

9. Could a small piece of solid sugar be dropped into the cooled liquid water instead of the piece of ice to obtain the results described above? Yes___ No___

Explain your answer:

10. Could ordinary tap water be used instead of distilled water to obtain the results described above? Yes___ No___

Explain your answer:

III. An experiment was conducted to determine if two pieces of metal would undergo diffusion when placed in contact with each other. A flat piece of polished gold and a flat piece of polished lead were clamped together and left in the laboratory for a year. When the clamp was removed at the end of a year, the piece of gold and the piece of lead were stuck together. The following conclusion was drawn from the results of this experiment:

"The experiment did not demonstrate diffusion because the pressure exerted by the clamp caused the two metals to melt and mix together."

11. Would you consider the experimental method described above as one representing the best possible method available to determine if two metals would undergo diffusion? Yes___ No___

Explain your answer:

12. Was sufficient information presented to conclude that the clamp caused the two metals to mix together? Yes___ No___

Explain your answer:

13. Can the results obtained with the gold and lead stuck together at the end of a year be explained according to Kinetic-Molecular Theory? Yes___ No___

Explain your answer:

14. Was it reasonable to conclude from the experimental conditions given that the pressure exerted by the clamp caused the two metals to melt? Yes___ No___

Explain your answer:

15. Is a year a suitable period of time for an experiment of this type? Yes___ No___

Explain your answer:

IV. Assume that equal quantities of CO_2 gas at (A) and H_2 gas at (B) are simultaneously injected into opposite ends of a long glass tube as shown in Figure 1 below. The glass tube contained air prior to the injection of the CO_2 and H_2 gases. The density of CO_2 is 44 grams per mole, and the density of H_2 is 2 grams per mole.

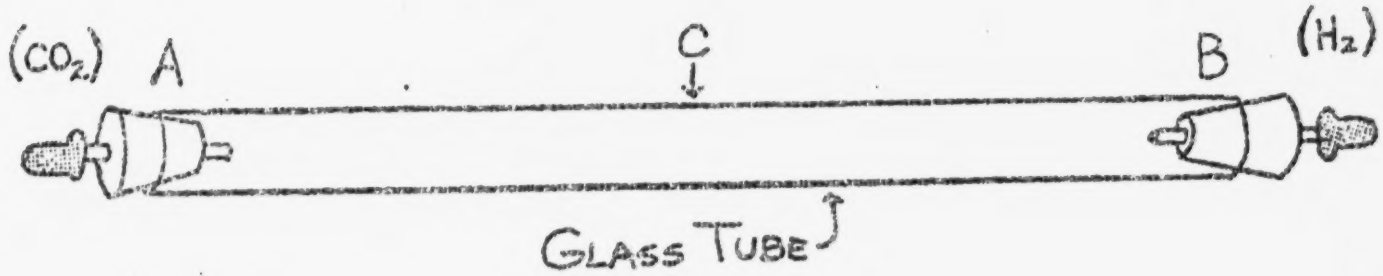

Figure 1

The following prediction of what would happen to the two injected gases was given:

"The two gases will meet at the center of the tube (C). Then the larger CO_2 molecules will push the smaller H_2 molecules back toward the end of the tube labeled (B). This will finally result in a much greater amount of gas at the end of the tube labeled (B)."

16. Can the prediction that the two gases will meet at the center of the tube (C) be explained according to our understanding of diffusion? Yes___ No___

Explain your answer:

17. Will our understanding of diffusion support the prediction that the larger CO_2 molecules push the smaller H_2 molecules backward? Yes___ No___

Explain your answer:

18. Does our understanding of diffusion support the prediction that the final concentration of gases at the end of the tube labeled (B) will be much greater than at the end of the tube labeled (A)? Yes___ No___

Explain your answer:

19. Suppose the experiment was repeated with the tube in a vertical position rather than the horizontal position as shown in Figure 1 and the same prediction was given. Could this prediction be explained according to our understanding of diffusion? Yes___ No___

Explain your answer:

20. In the situation described, it was mentioned that the tube contained air before the H_2 and CO_2 gases were injected. Could the same prediction be used for the final distribution of the H_2 and CO_2 gases if the tube had been evacuated prior to injecting the two gases? Yes___ No___

Explain your answer:

V. Many people have the opinion that when a person drinks a liquid through a straw the liquid is pulled up through the straw by suction. The following experiment was used in an attempt to show that, during the process of drinking a liquid through a straw, air pressure actually pushes the liquid up the straw and it is not pulled up by suction.

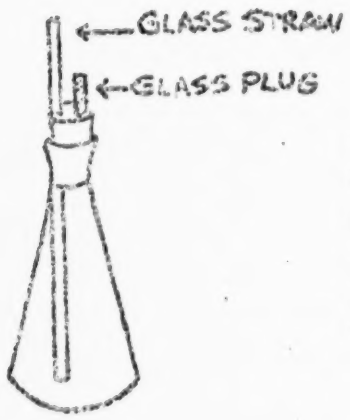

Figure 2

Experiment

An Erlenmeyer flash was filled completely full of water. A rubber stopper containing a glass straw and a glass plug was inserted into the flask. When a student was told to "drink" the water from the flask, he could not get any water to come up through the straw.

After the glass plug was removed from the rubber stopper and the same student was told to "drink" the water from the flask, he was able to get the water through the straw.

21. Does the experiment demonstrate that air pressure pushes the liquid through the straw? Yes___ No___

Explain your answer:

22. Would the Kinetic-Molecular Theory of gases support the results obtained from the experiments?
Yes___ No___

Explain your answer:

23. Does the experiment represent a good method of demonstrating that liquids are not pulled up through a straw by suction?

Explain your answer:

24. Does the Kinetic-Molecular Theory of gases support the idea (opinion) that liquids are pulled up through the straw by suction? Yes___ No___

Explain your answer:

25. Would you expect the same results to occur from the experiment if the flask had been one-half full of water instead of completely full of water?
Yes___ No___

Explain your answer:

VI. A mechanical apparatus designed to rub two blocks of ice together was constructed. This ice-rubbing apparatus was placed in a freezer having a temperature of 0°C and a pressure of 760 mm Hg. It was loaded with two blocks of ice, each with sides about 15cm. long. During the process of rubbing them together, the two blocks of ice melted at the contact surfaces, and the melted ice ran down the side of the lower block and froze again.

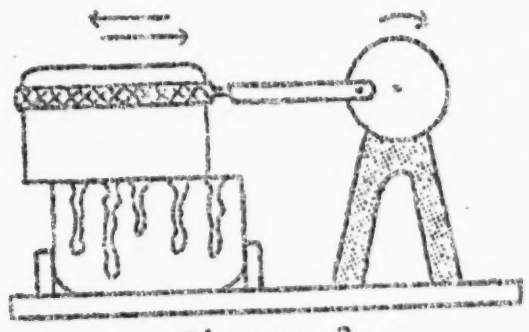

Figure 3

26. Could the melting of the ice observed at the rubbed surfaces be explained by the Kinetic-Molecular Theory of matter? Yes___ No___

Explain your answer:

27. The rate of speed at which the two blocks of ice were rubbed together affected the rate at which the ice melted. Can this be explained by the Kinetic-Molecular Theory of matter? Yes___ No___

Explain your answer:

28. When the temperature of the freezer was changed to -20°C without changing the pressure, the ice did not melt when the two blocks were rubbed together. Can this be explained by the Kinetic-Molecular Theory of matter? Yes___ No___

Explain your answer:

29. Does the diagram (Figure 3) represent a good illustration to use with the description given? Yes___ No___

Explain your answer:

30. If the diagram (Figure 3) was presented alone without the written description, could question 28 be answered? Yes___ No___

Explain your answer:

VII. According to Kinetic-Molecular Theory, the molecules of gases are in constant motion. However, let's consider a model for gases in which the molecules of gases are not in motion. In this model for gases, molecules are still considered as small particles with van der Waals forces existing between them; the particles are separated by large distances. It is claimed that this model for gases in which the molecules are stationary is just as useful in explaining the properties of gases as the model in which the molecules are in motion.

31. Would this model for gases, in which the molecules are stationary, be useful to explain the mixing of two gases at standard temperature and pressure (STP)? Yes___ No___

Explain your answer:

32. Would this model for gases be useful to explain the condensation of a gas into a liquid? Yes___ No___

Explain your answer:

33. Would it be possible to explain a change in the kinetic energy of gases by using this model for gases? Yes___ No___

Explain your answer:

34. Would the model for gases in which the molecules are stationary be useful to explain the gas law (Charles) relating temperature and gas colume at a constant pressure? Yes___ No___

Explain your answer:

35. Would this model of gases be useful to explain Avogadros's Law, "Equal volumes of all gases under the same conditions of temperature and pressure contain the same number of molecules?" Yes___ No___

Explain your answer:

VIII. The following problem was given.

Problem:

200 ml of hydrogen gas are collected at a pressure of 800 mm Hg and a temperature of 10°C. When the conditions are changed to a pressure of 760 mm Hg and a temperature of 27°C, what volume will the 200 ml of hydrogen gas occupy?

The following procedure and solution were presented for the problem given above.

Procedure:

1. Correct for the change in pressure. If the pressure decreases, P_1/P_2 will be greater than 1; if the pressure increases, P_1/P_2 will be less than 1.

2. Correct for the change in temperature. If the temperature decreases, T_2/T_1 will be less than 1; if the temperature increases, T_2/T_1 will be greater than 1.

3. Substitute the appropriate values in the combined gas law relation and solve for V_2.

Solution:

$V_2 = V_1 \times$ Correction for P x Correction for T.

$$V_2 = 200 \text{ ml} \times \frac{800 \text{ mm Hg}}{760 \text{ mm Hg}} \times \frac{27°C}{10°C}$$

$V_2 = 567$ ml

36. Was sufficient data given in the problem to enable one to arrive at a correct solution? Yes___ No___

Explain your answer:

37. Was a correct procedure used for solving the problem?
Yes___ No___

Explain your answer:

38. Could other procedures be used for solving the problem? Yes___ No___

Explain your answer:

39. If the pressure had been given in atmospheres rather than mm Hg, would it be possible to use the same procedure to solve the problem correctly? Yes___ No___

Explain your answer?

40. If the temperature had been given in °K rather than °C, would it be possible to use the same procedure to solve the problem correctly? Yes___ No___

Explain your answer?

IX. The solid lines in the graph below show the velocity distribution at each of two different temperatures; 0°C and 500°C, for a large number of molecules having the same mass.

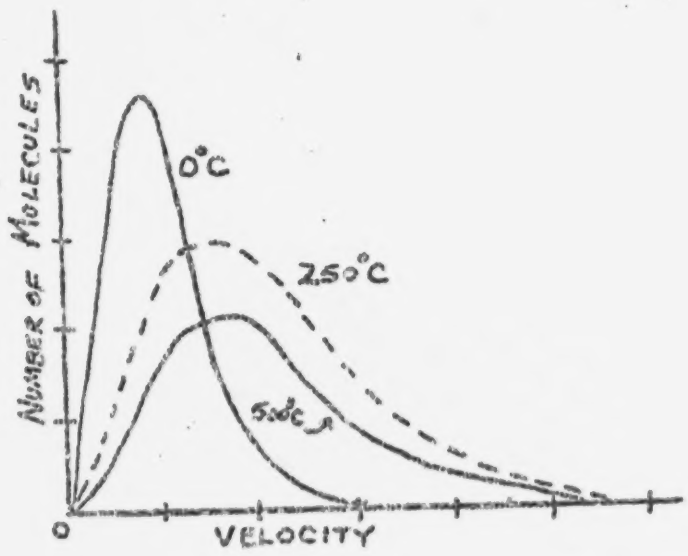

Figure 4

41. It has been claimed that this graph represents molecules of any substance and is not specific for just the molecules of one substance. Do you agree? Yes___ No___

Explain your answer:

42. Would you agree that to be useful, the graph must indicate whether the molecules represent a solid, liquid, or a gas? Yes___ No___

Explain your answer:

43. Based on the assumption that the two curves for 0°C and 500°C are correct, it was claimed that the broken line accurately represents the curve for 250°C. Do you agree? Yes___ No___

Explain your answer:

44. The kinetic energy of a gas is a function of the molecular velocity, KE = 1/2 mv^2. Therefore, would you agree that the graph represents the kinetic energy distribution of a large collection of molecules of the same mass? Yes___ No___

Explain your answer:

45. Do you agree that one can infer from the graph that when heat is added to the molecules, it increases both the velocity and the kinetic energy of the molecules? Yes___ No___

Explain your answer: